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ABSTRACT

The early intellectual development in mathematics and science for boys and girls, as determined by test scores, is discussed in this conference presentation. Factors that might account for differences between female and male students' performance, such as course experiences, are explored. The problem of female students often being shortchanged in their science and mathematics experiences and not being expected to do well is cited. Programs are described which convey the value and utility of mathematics and which encourage young women to take high school mathematics courses as pre-requisites for later college courses. Also examined are: sex differences in self-reporting of high school studies and intended areas of college study, special problems of minority women, and reasons in attrition of women in science/mathematics fields during their college years. A plan is presented for improving the quality of education provided to all students, from kindergarten to graduate level. Reactions of Carolyn Callahan and Nicholas Colangelo are appended. (JDD)

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# BRILLIANT WOMEN FOR SCIENCE, MATHEMATICS AND ENGINEERING: GETTING MORE THAN WE DESERVED?

**Shirley Malcolm**

"It's a girl!" The news of the arrival of a daughter all too often signals the beginning of a pattern of socialization that may extend even to the choices of career in adulthood, independent of her interests or aptitude. Her pink booties give way to ballet slippers. The gentler pattern of play and interaction by her parents while she is an infant is often followed in her childhood by expectations and assumptions about her toys *and* her abilities in mathematics. Breaking this cycle of socialization may be necessary if we are to attract and retain highly talented young women to science and engineering careers.

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In 1986, women were about 44% of all workers in the United States workforce, a comparable percent of all professional and technical workers, but only 15% of employed scientists and engineers. While this proportion is low, it has increased, tremendously, since 1976 when women were only 9% of scientists and engineers. Women's participation is higher in science (around 25%) than in engineering (around 4%). Scientists and engineers are made, not born. Finding the raw talent, cutting and polishing it to its full brilliance, is responsibility shared across our schools, our colleges and universities, and the science and engineering communities.

Early identification of talent for science, mathematics and engineering means identifying (or making certain assumptions about) the characteristics most likely associated with people who are scientists, mathematicians and engineers. This is usually done by referring to characteristics of the present population of professionals in these fields. These elements may include personal attributes such as interest, curiosity, persistence and hard work, coupled with above average intelligence. No matter how strong these aspects are, however, we generally accept the notion that a suitable environment to learn, encouragement and the guidance of teachers and mentors are essential to having the potential for science expressed as performance and achievement in these fields. We must look both at the personal attributes they bring and the way these interact with the environment they encounter to determine if talented young women are receiving the experiences that would encourage or support their choice of a science career.

Since our reference points for identifying talent have been the males who have dominated these careers, we may not have included those attributes of potential women scientists who, unable or unwilling to buy into the image, may have been left behind. We may agree that intellectual capability is central, but may disagree on the narrowness of current measures used to assess this. Clearly, our society is geared to believe that, at least in mathematics learning, ability is of prime importance; you can identify it early and it is immutable - you either have it or you don't. In a recent survey of American and Japanese mothers, both groups were asked about the reasons for school success in mathematics. The American mothers attributed this to ability; the Japanese mothers attributed such success to effort! If we ignore for a moment the issue of test bias, what do the tests tell us about the capability of girls and boys to do science?

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If we used measures of achievement by nine year-old on the National Assessment of Educational Progress in science, mathematics and reading as proxy measures of educational capability, all else being equal, we would expect to find females as numerous as males in science, engineering and mathematics based careers. At this point, girls perform as well as or better than boys on the NAEP mathematics test in all tested areas including knowledge, skills, understanding and applications. Science scores are slightly higher for nine year old males on all components, with the largest difference (2.6 percentage points) on the attitude component. (Reported in NSF, 1988.) Nine years old females outperform nine year old males on the NAEP reading test (NAEP, 1985).

At thirteen years of ages, score differences between males and females become larger and begin to favor males, especially in science. Mathematics scores are still very similar between the two groups: girls score slightly higher on the skills component of the test, and boys score slightly higher on applications. On the NAEP science test, males outscore females, with performance differences of more than four percentage points on science, technology, and society; content; and attitude. Females maintain their performance advantage over males on the NAEP reading test.

By seventeen years of age the score differences in mathematics and science on NAEP have increased in favor of males. The female advantage in reading is maintained for 17 year-olds.

How do girls who start off even or superior to boys in their performance in mathematics fall progressively behind over time? Why are score differences present from the first point of testing in science; and why do they become more pronounced over time? A number of possible explanations exist, including:

- Males and females take different science and mathematics courses in school;
- Males and females have different experiences in the classes which they share; and
- Males and females have different out-of-school experiences which affect their test performance.

**Different Courses**

Based on data from High School and Beyond (HSB) we find that females are as likely as males to enroll in an academic level high school program. We find that young women take fewer mathematics and science courses in high school but have higher grade point averages than young men. If we look at specific courses, we find that females are about as likely as males to attempt algebra I, geometry, algebra II, biology and chemistry. On the other hand, 25.8% of males and 20% of females attempted trigonometry; 9.9% of males and 7.8% of females attempted analysis and 8.2% of males and 5.7% of females attempted calculus in high school; 5.2% of males students attempted chemistry II, compared with 3.6% of females. The male advantage in physics was substantial. Over 22.1% of young men and only

11.6% of young women reported attempting physics. Advanced physics was reported taken by 2.6% of men and 0.9% of women in the study (Reported in NSF, 1988).

Clearly, the young women in the nationally drawn HSB population were not getting the same course experiences as the young men. So, the fact that differences in performance occur among 17 year-old should come as no surprise.

Any differences that are seen for 13 year old males and females, even small ones, are not as easily explained, however, since presumably, at this point all students take the same courses.

What other factors might be at work to account for differences seen between female and male students' performance in science and mathematics?

**"A Different World"**

In a paper presented at a National Research Council conference, "Women: Their Underrepresentation and Career Differentials in Science and Engineering" Matyas and Kahle summarized the research on pre college factors affecting the achievement of females in science and mathematics education; they found the following:

- Girls and boys enter elementary school with equal interest in science but with unequal experiences.
- Girls and boys have different out-of-school activities, with boys having more opportunity for hands-on experiences that are important for in-school science and mathematics learning.
- Girls and boys have an image of scientists as being white, male and "nerdish/bookish".
- Girls have less opportunity than boys to handle equipment, perform experiments and undertake other science activities in the classroom.
- Boys are expected to perform better in mathematics than girls and receive more teacher interaction on their mathematics performance.
- Teachers, especially in mathematics and science, call on a small target group of students (mostly boys) in the classroom with whom they interact for longer periods of time.
- Boys tend to be asked higher cognitive level questions than girls.

The picture that emerges is one in which female students, even while taking the same classes as male students, are drastically shortchanged in their science and mathematics experiences and opportunity for interaction with the teacher; they are outsiders, bringing neither the base of out-of-school experiences nor enabled with appropriate in-school ones. They are not expected to do well in science and mathematics, and often they fulfill these expectations.

A particularly troubling finding which was presented by Matyas and Kahle was the experimental study of Spear, where science teachers were asked to evaluate the sample work of students.

> When teachers believed that the work had been done by a boy, it was judged more scientifically accurate, possessing better organization and richer ideas, and more concise than when they believed a girl had done the same work. Girls' work was judged to be neater than boys' work.

Other instances of differential behavior cited included the work of Gordon and Addison who documented that teachers are more likely to nominate boys of average abilities for special programs before girls who are gifted.

In attempting to piece together a picture of how these various factors may interact in women's decisions to participate or not to participate in science, Chipman, a discussant at the NRC conference, posed the following model (Figure 1). She suggests that two major factors contribute to the participation--- "expectancy of success and value assigned to outcome." Each of these factors she suggests is affected by many other inputs (Figures 2 and 3). She states, "for individuals, it is clear that cognitive ability is an important predictor of persistence in mathematical, scientific and technical fields, but it is rather unlikely that sex differences in ability contribute significantly to the observed sex differences in participation.

Chipman goes on to suggest that different interest patterns and *confidence in ability* may provide some explanation for observed sex differences in participation.

What are the relative roles of interest, ability, "preparedness," confidence in ability and competence in determining females' participation in science careers? Are you born interested in science and mathematics and made uninterested? And, can interest, unmade or unborn, be stimulated?

If we believe, as evidence suggests, that young children are born curious, possessing all the qualities of inquisitiveness, exploration, wonder, openness and excitement which we attribute to "good" scientists, then we must look to those later experiences and interactions with the adult work to determine how that interest is reduced.

Chipman questions whether interest in science, mathematics and technology is spread across the population in the same way and whether we should expect to find it manifest among men and women to the same extent. Chipman's question is put in a different light when we realize that one can find islands of equity spread across the landscape of the United States educational system--classrooms and schools where young women are as likely to be enrolled in advanced math and science as young men. And, the teachers of those classes expect as much from the female students as they do from the male, call on members of both groups equally, wait for their answers, equally encourage their participation (Casserly, 1983 & Kahle, 1983).

**Changing Habits of Mind**

In 1973 sociologist Lucy Sells looked at the entering freshman class at the University of California at Berkeley and noted the different ways that men and women were distributed among the major - the men dominated in majors of engineering, mathematics and natural science, the women in the social sciences, humanities and education. She confirmed this same distribution among majors at the University of Maryland. Sells found the connection between majors and gender and the mathematics courses taken in high school. Even if the women decided that they were interested in civil engineering or chemistry, they were too often prohibited from choosing this major because they had not taken the requisite levels of mathematics in high school. In making a choice that was possible, given their mathematics preparation, these women were limited to those majors that did not require four full years of academic track mathematics. Mathematics came to be described as the "critical filter" for careers in science, mathematics and engineering, and a program of research and intervention was begun which has occupied scholars and activists alike for almost a decade and a half. These have included interventions, mostly from the middle grades through college, as with the women in engineering programs.

Intervention programs were developed that focused on:

- Trying to get able young women to keep their options open by continuing to take mathematics courses offered at the high school level, and

- Conveying the *value* and *utility* of mathematics to women's lives and to later career decisions.

Such programs took the form of career education workshops such as "Expanding Your Horizons," developed by the Bay Area Mathematics/Science Network, that focused on informing students and parents about the importance of taking mathematics in high school. Programs for teachers and other school personnel, such as EQUALS of the Lawrence Hall of Science, University of California, Berkeley, quickly spread across the United States. Attention to mathematics as a "critical filter" was paid in books, magazines and newspaper articles, films and film strips. Sex equity programs that resulted from federal enforcement of Title IX, included mathematics and science prominently among their concerns.

The Women in Science Program of the National Science Foundation (NSF) was a primary source of support from women's intervention programs, funding 136 projects between 1976 and 1981. The Women's Educational Equity Act (WEEA) program, established in 1974 at the Department of Health, Education and Welfare was another major source of funding for science-related programs under its general mandate to support the movement of women into careers non-traditional to them.

While it is difficult to document the direct effect of a single exposure career day on the life of a young woman, one sees amazing correlation between the onset of the "movement" in the early 1970's of which the career days were a part, and the upward climb of degree output by women over the succeeding decade. In 1972,

501 women received bachelor's degrees in engineering. By 1980, 6,014 women received such degrees, and by 1982, this number had reached 8,231. (Vetter and Babco, 1987) In 1986, women received 11,049 engineering bachelor's degrees, or 14.5% of the total awarded.

In summary, the steps leading to altered high school course-taking for young women in the late 1970's and 1980's seem to have been:

- The identification of mathematics as a "critical filter" to science and engineering, and indeed to many other professional careers, as well;
- The dissemination of this information and initiation of intervention programs to affect young women's choices by stressing the utility of elective mathematics course taking; and
- Programs aimed at teachers and parents to inform them of their role in high school mathematics course taking by young women.

While career information about all kinds of fields, especially non-traditional ones, was delivered, the focus of the message was clearly to "keep your options open" for many different futures that might await. Clearly, an increased number of young women, their teachers and parents got the message. Young women became distributed in engineering fields, for example, where only a few years before, they had been only a token presence.

**Interest**

If we believe that little girls start out with as strong an interest in science and as much ability as little boys, where might we look for an explanation of the differences that emerge:

- Who teaches science? One could argue that students receive a clear message about females' place in science from the role models in the classroom. According to Weiss, in grades K-3, teachers spend an average of 19 minutes per day on science instruction; this increases to 38 minutes for grades 4-6. While this mostly female teaching workforce enjoys teaching science. Few feel that they are "master" teachers in the subject with over one-fifth feeling they are not well qualified to teach physical science or earth/space science. By high school, the science teaching workforce has become overwhelmingly male (68%), and a full 61% agree or strongly agree that they consider themselves a "master" teacher in science. The perceived (and actual) competence in teaching science increases as the female proportion decreases.
- How is it taught? Science is typically taught with more time spent in lecture and discussion than in hands-on lab experiences. Teachers overwhelmingly agree that hands-on classes are more effective. Research supports the particular effectiveness of this technique when used with minority and female students. But, there is a large discrepancy between the most desirable and the actual conditions for learning. There is heavy reliance on textbooks which have tended not to show an active role for girls and women in science. As grade level

increases, the amount of time spent on lecture and "whole class activities" increases while the proportion of time spent on small group activities decreases. Small group activities and team project activities have been shown to be particularly effective for female students. (Malcolm, et al., 1984).

- What is taught? There are those who would say that the content of science and mathematics courses are free of bias. It is not difficult to point to problems and examples that draw on the experience of boys rather than girls. Questions of bias in the presentation of content are relatively new areas of exploration. But only a few examples are required to point out how this might work. In all my black inner city high schools in Birmingham, we "learned" about vectors using text-based examples of sailboats--something that few, if any of us had seen, no less experienced. Discussions of social organization often draw on language such as "dominant" male, harem and the like. We talk about a man-made world; and, only white men did important things in science since they dominate in the texts. Women are left on their own to draw conclusions as to why they are "missing persons." Students are not told of important figures who worked in spite of the odds, in spite of barriers erected to keep women out.

**College Bound**

If you look at the characteristics of college bound students based on the Admissions Testing Program of the College Board, we find major differences in self-report of the high school studies and intended areas of study for male and female students in 1985:

| **% of Students Taking** | **Male** | **Female** |
|---|---|---|
| - 4 or more years of math | 73.0 | 60.9 |
| - 2 or more years of biological science | 33.3 | 36.6 |
| - 3 or more years of physical science | 33.3 | 20.0 |
| **% of Students** | | |
| - Having 3.50 g.p.a. or above | 34.4 | 27.0 |
| - In top tenth of his high school class | 20.5 | 21.9 |
| **% of Expressing as First Choice Intended Areas of Study** | | |
| - Agriculture | 1.4 | 0.6 |
| - Biological Sciences | 3.0 | 3.1 |
| - Forestry/Conservation | 0.6 | 0.1 |
| - Health and Medical | 9.1 | 19.0 |
| - Computer Science/Systems Analysis | 9.4 | 5.0 |
| - Engineering | 21.1 | 3.4 |
| - Mathematics | 1.2 | 1.1 |
| - Physical Sciences | 2.5 | 1.0 |

The problem of attracting women to science, mathematics and engineering is not solved. Able young women who are headed to college are still making different choices of majors than able young men. Subtle social factors often play a role in their decisions.

**The Times Are A'changin'?**

Looking at the 20 year trends in *The American Freshman* we find that women's aspirations for the doctorate and professional degrees have increased tremendously, with fully 18% of women compared to 19.6% of men indicating that they planned such a degree. Over the same period, women's interest in education decreased, from 17.5% in 1966 to 10.4% in 1985; their interest in business skyrocketed from 10.9% in 1966 to 23.8% in 1985; and their expected participation in engineering increased from 0.3% in 1966 to 3.0% in 1985.

In 1967 over 44% of women agreed strongly or agreed somewhat with the statement "The activities of married women are best confined to the home and family." By 1985 the number agreeing had dropped to 16.0%, and by 1987 it had risen slightly to 20.3%. By contrast, 66.5% of men in 1967 agreed with this statement and 29.5% in 1985. By 1987 this number had risen to 32.3% of freshman males. Is commitment to a career in science compatible with this view of the role of women? Clearly, young women's perception of the conflict of career and family must be addressed; and even more so, the perception of young male students. Ultimately, the reality of these conflicts must be dealt with by the society at large. These attitudes fly in the face of the reality of the world today, since we know that most of these women will work outside of the home. And the faculty makeup of most colleges and universities, especially in science and engineering, and the status of these women in science does little to send an alternative message.

**Special Populations**

Minority women with interest and aptitude in science or engineering face special problems since they face barriers related to race and sex in pursuing such careers (Malcolm, et al. 1967). The low expectations and lack of access to quality science and mathematics education which limit choices for American Indian, Black and Hispanic youth affect their participation in science compared to the majority. Expectations about the role of women serve to limit these women further. They are most unlike the image and likely to be overlooked as promising scientists or engineers for this reason.

Although Black women complete high school and attend college at much higher rates than Black men, proportions do not carry over in science and engineering fields. Black women were 11% of all employed women in 1986 but only around 5% of employed women scientists and engineers. On the other hand, Asian women were over 5% of women scientists and engineers (over one-fifth of whom were non U. S. citizens), while only 2% of women in the U. S. workforce were Asian.

American Indian, Black and Hispanic women who were given the opportunity to tell their stories in a 1975 conference on Minority Women in Science recalled stories of misassignment to classes for mentally retarded students by virtue of

tests given in English to non-English speakers, of counselors who discouraged their pursuit of science and urged them toward more traditional careers, of peers and family who did not understand their choices. It is not clear how much has changed in the thirteen years since the conference.

Disabled women, like disabled persons in general, face barriers to excellent science education. These barriers may take the form of low expectations of teachers, parents and counselors; denial of access to classes or laboratories; lack of appropriate materials to accommodate their disabilities (e.g. textbooks on ape or raised models); or inappropriate test of their capabilities.

The physical disability becomes the major focus rather than the intellectual capability. In addition, under the guise of protecting a daughter with a physical disability, parents may, inadvertently, delay her gaining independence and limit her participation in path-breaking, non-traditional activities.

When viewed in this manner, it is a wonder that minority and disabled women make it into science or engineering at all.

**Life After High School**

While the interest of young women in science and engineering is lower than that of young men at grade 10 and at entry into college, the pipeline is, by no means, closed to them. Analysis of High School and Beyond data reveal "dropping back into science" as late as the sophomore year of college. This phenomenon was quite strong among non-traditional science students - women and minorities. Of course, one's ability to "drop back in" will be dependent on whether the appropriate coursework, especially mathematics, was completed in high school. Even the talented women who declare their intention to major in mathematics, science and engineering fields do not all make it to graduation day with degrees in these fields. Neither do the young men, but the losses are greater for the young women.

We can speculate on the causes of the greater losses of women students from the science education pipeline. Most of the reasons have little to do with academic ability, but relate to affective and environment issues. The literature review would lead to discussions of such topics as:

- *Campus climate.* Do women get the idea that they are really wanted in the school, in the department, in the classroom, in the laboratory?

- *Critical mass.* Is there a token presence of women as students as well as faculty or are the numbers significant?

- *Support system.* Are women isolated or made to feel this way? Are they included in the informal networks of students or in constructive mentor relationships with faculty?

- *Confidence in abilities.* Is the college experience affirming for young women? Is there adequate feedback on their performance and their potential compared with other students? Are they encouraged to

participate in confidence building activities such as undergraduate research?

When things don't work well, the young men blame the system; the young women blame themselves. They fail to recognize that the problem is not with them.

**The Bottom Line**

In 1986, Ph.D.'s in mathematics were awarded to 367 U. S. citizens, 298 to men and 69 (about 19%) to women (NRC, 1987). Seven years earlier (1978-79) women earned 41.7% of bachelor's degrees and in 1981-82, 32.2% of master's degrees in mathematics. (Vetter and Babco, 1987). A similar pattern of loss at each succeeding level of the pipeline can be seen for women across science and engineering fields. Perhaps the question is only partly one of *finding* brilliant women, but also of keeping them once found. Science, mathematics and engineering may not be getting their "fair share" of the best and brightest women, but perhaps these fields are getting more than they deserve! While these fields have tremendous intrinsic rewards are the costs of attaining them and working in them made too high for women? Is there a "survival of the fittest" mentality, in science, focused supposedly on weeding out the less able? Are the barriers and screens erected to filter intellectual ability and creativity, and do these work the same for men and women?

The medical profession has recently gone through a self-examination to assess whether the academic filters which have been erected over the years have, in fact, given us the kind of doctors we want, and their conclusion was an emphatic, "no." Too much emphasis was placed on the cognitive aspects, ignoring the personal qualities that separate the healer from the mere technicians.

Do we allow students to choose based on the reality of science-the fun, the excitement of discovery, the mental challenge-or do we ask them, instead, to survive the drudgery with no sense of vision-memorizing interminable lists of terms or dealing with concepts only in the abstracts?

**A Plan for Reform**

Since there is a system of problems which keep the numbers of women scientists, engineers and mathematicians at reduced levels only a system of solutions spanning across educational levels can be expected to remove the barriers to full participation. The research suggests some of following elements as part of a system of reform.

We must improve the quality of education in science, mathematics and technology which is provided to all students.

**Grades K-6**

**Teachers**

- Increase teachers' level of content knowledge and confidence.
- Include in the preservice and inservice education of teachers those specified pedagogical skills known to be associated with equitable practice, such as cooperative learning and team projects, peer tutoring, wait time.
- Stress the need for high levels of expectations for all students.

**Curriculum and Instruction**

- Increase the number of examples drawn from the experiences which girls more often bring to the classroom.
- Increase the opportunity for hands-on activity in science and mathematics.
- Stress experience with phenomena rather than acquisition of terminology through memorization.
- Increase the coverage of topics in the physical and earth sciences, geometry, estimation, mental arithmetic, probability and statistics, problem identification and formulation.
- Introduce technology as a specific content area.
- Embed research on equitable practice into the curriculum.
- Stress development of higher order skills and relationship of science, technology and mathematics to everyday experiences.

**Texts and Other Materials** (should reflect criteria specified above)

- Choose materials which show women in active roles in science and mathematics.

**Out-of-School**

- Specifically encourage girls' participation in science projects.
- Mention a specific interest in science, math and technology to parents in conference, and encourage gifts of books and toys that support this.
- Promote student use of books and television programs on science, mathematics and technology.

**Grades 7-9**

- Provide teachers with specific strategies for equitable instruction with students of this age group.
- Stress active involvement of students in learning science, mathematics and technology, for example, team projects.
- Assign teams of students to develop projects, especially in the physical sciences. It may be necessary to begin with single sex groupings so that young women are not intimidated by young men.
- Choose topics that cut across/integrate physical and biological sciences and technology, e.g., designing an assistive device for a person with a physical disability, or a space station.
- Encourage young women to take algebra as soon as possible, and to continue taking science and mathematics throughout high school. Especially encourage taking chemistry and physics, the courses which young women tend to actively avoid or, by default, end up not taking.
- Encourage young women's involvement in science projects, especially those that involve the science and mathematics in those activities in which girls may be more involved, e.g. the physics of dance, the mathematics of basketball, kitchen chemistry.

**Grades 10-12** (In addition to all of the above)

- Give female and male students feedback on their performance and potential. Especially, reach out to and encourage non-traditional students.
- Stress the usefulness of science, mathematics and technology for everyday life and the relationship of studying these fields to future careers.
- Encourage the most talented students and those with strong potential to take advantage of summer, after school or Saturday programs that support their science, mathematics and technology learning. Be sure to include female students.

**College**

- Provide a support structure for young women majoring in non-traditional fields, including (but not limited to) recruitment, orientation to the major and to campus life, bridge programs, seminars that deal specifically with the potential conflict of career and family, counseling.

- Provide opportunity for early involvement in research as an undergraduate. Especially, target those able women who may not accurately assess their own potential for graduate study.

- Encourage summer employment/internships that will allow students to see what kind of work scientists really do.

- Address the problem of college level science, mathematics and engineering instruction. Provide specific skills or teaching techniques to improve undergraduate instruction.

**Graduate and Professional**

- By junior year in college, assist students in negotiating the graduate school experience by specific counseling on choosing a mentor, choosing a graduate program, the expectations of a graduate student, financing graduate education, etc.

- Examine each list of nominations for awards, fellowships, special research experiences, to make sure that qualified females have not been overlooked.

- Faculty must give regular feedback and encouragement to female graduate students.

- Faculty must not tolerate sexist remarks or behavior from students and must challenge such from other faculty.

- Support reasonable provisions for dependent care.

- Support flexible schedules for tenure review, to accommodate tenure line faculty who may become disabled, who are injured in an accident or who may face pressing family responsibilities such as illness of dependent parents, children or other life crises.

This list is not intended to be exhaustive, merely suggestive of the type of systematic change which needs to be considered by the community of science, mathematics and engineering-fields facing shortage, and competition for talent from many other areas. Academic science, in particular, may find it hard to compete with industry in terms of salaries and benefits.

We can no longer afford the "weeding" that we have been doing. We must be able to draw on the talent from among that two-thirds of the pool which has not been cultivated for science and engineering.

Our future depends on our ability to rise to this challenge.

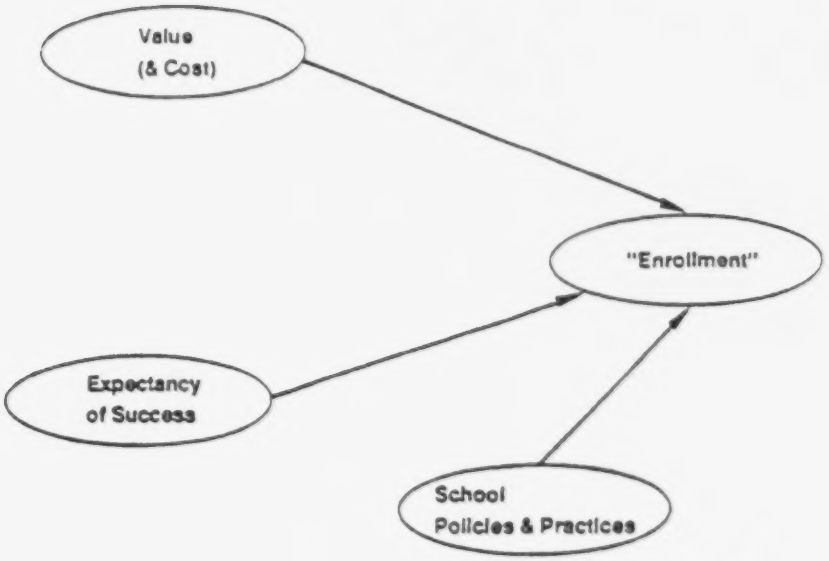


Figure 1 - Core of the Model

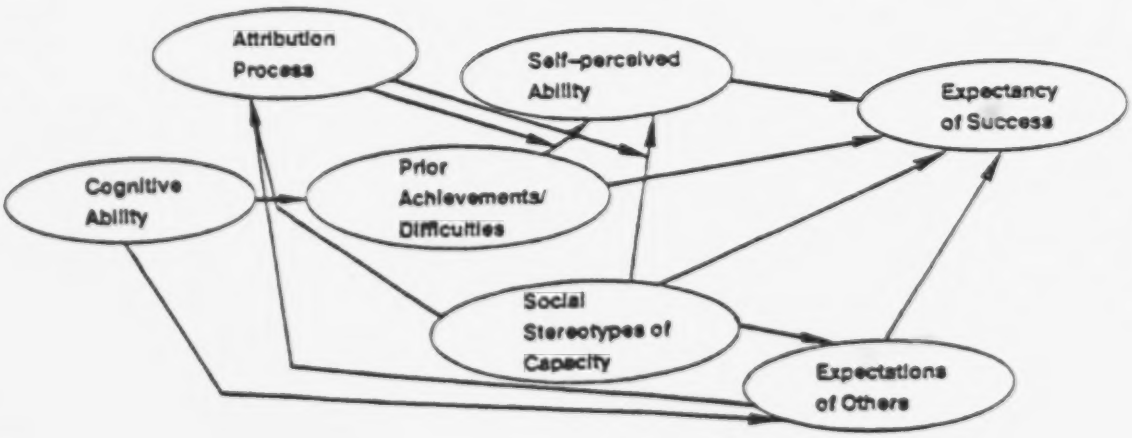


Figure 2 - Influences on expectancy

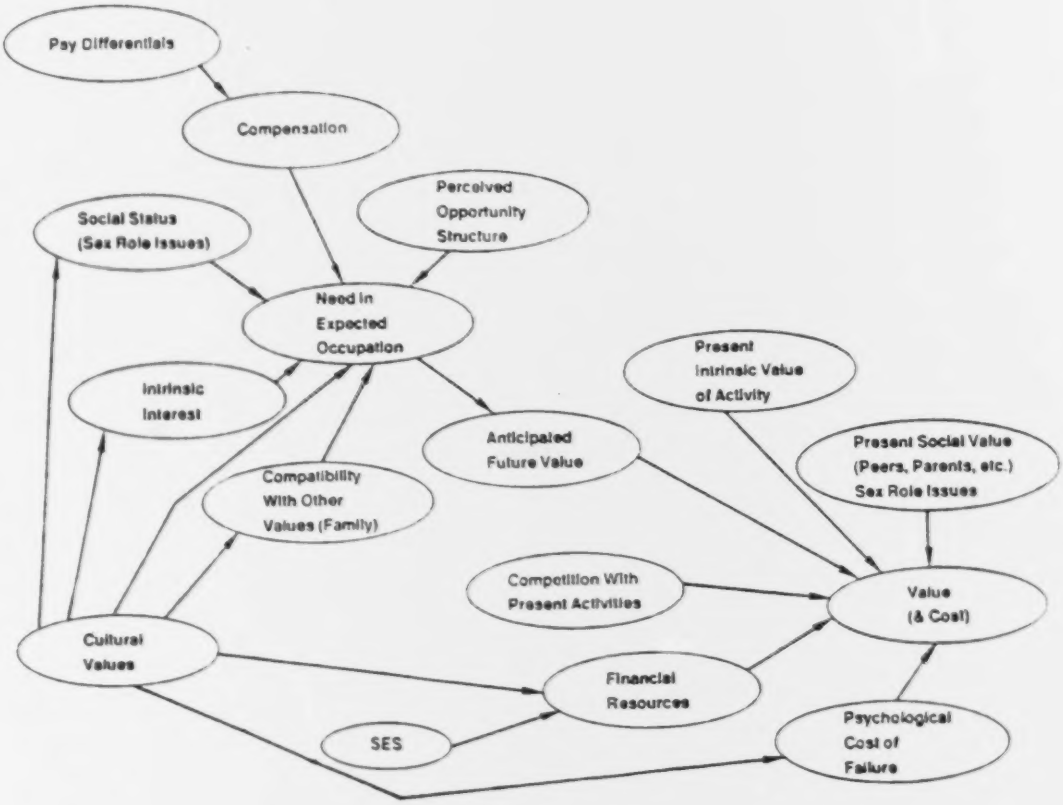


**Figure 3 - Influences on value**

**Discussant Reaction:**
**Brilliant Women for Science, Mathematics, and Engineering:**
**Getting More Than We Deserve?**

**Carolyn M. Callahan**

Shirley Malcolm asks the question, "Are we getting more than we deserve?" Her paper and the extensive study of the factors which have inhibited the achievement of females in mathematics, science, and technology are testimony to an emphatic "Yes" as an answer. The degree to which women have elected careers in mathematics, science, and technology and have managed to accomplish their goals is testimony to extraordinary efforts on the part of those women to overcome the stereotypes, biases, and cultural influences which work against such accomplishment and to those parents, friends, counselors, mentors, and programs that have provided the necessary support to these women.

Further, the categories of factors which Malcolm provides to account for differential achievement are useful in organizing our thinking about ways to modify those circumstances. I would, however, break out the "out-of-school experiences which influence test scores" to coincide with the influences of Chipman's model and to include factors which specifically influence the attribution process, the development of self-esteem, values--social, cultural, and intrinsic--and perceived ability in mathematics and science. That is, I would suggest we add these other categories which may not be completely independent categories, but which may help us ensure full attention to all relevant factors.

- The experiences which students have in school--not in class (in counseling situations, in social groups, in athletic programs, etc.)

- The attitudes and expectations of significant others

Although the last category will certainly be influential in creating experiences in and out of school, it would seem necessary to stress their importance by creating a specific category.

Another factor which seems critical for our consideration is the sex-role stereotyping of science and mathematics-related careers. Farmer (1987) has demonstrated that young women who are at the age of deciding on careers (late adolescence) most value personal interactions and have very strong social values (wishing to make a significant contribution to society). These same women perceive science and mathematics-related careers to be of a nature where all or nearly all work is individual, requiring social isolation both because of the setting and the demands that one work endless hours and to be so theoretical and abstract as to be of no practical value to society. Because they thus perceive that they will be unable to have meaningful relationships with people because of the work setting and the demands and that the work has no socially redeeming features, they reject those careers as options. She suggests that one of our missions must be to educate young women on the real variety possible in careers in these fields.

Eccles' research (Eccles, Adler, and Meece, 1984) also leads us to the importance of the family and of society in general in the development of young women's self-esteem, aspirations, and ultimate achievement. Further, Betz and Fitzgerald (1987) have included working mother (role model), supportive father,

highly educated parents, female role models and androgynous upbringing, liberated sex role values, androgynous personality, high self-esteems, and strong academic self-concept (These latter two variables have been demonstrated as related to parent perceptions among gifted females.) as factors, among others which are facilitative of women's non-traditional career choice.

Malcolm suggests that one strategy for improving the quality of education in science, mathematics, and engineering is to introduce science as a specific content area. While that is a curriculum decision which seems warranted in general in light of current developments, it is important to examine the ways in which such a decision may or may not enhance the development of interests and achievements of females. I will use the computer and computer skills as an example since we have had some experience with this technology. Unfortunately, the rapid introduction of computers into education without careful consideration of instructional strategies and the implications of choice on what and how to teach that technology may have contributed to *increased* differences in male and female achievements and attitudes. For example, Sanders and Stone in *The Neuter Computer* (1986) point out that there is a great gender gap in the use of computers in school. Among citations too numerous to go into here, they note that in one study, only one-fourth of those junior high and middle school students who used computers on an optional basis were females; in another study 40 percent of high school boys used the computer during free periods while only 8 percent of females did; and a survey of high school programming courses in California, Maryland, and Michigan showed that boys outnumbered girls two to one. Many of the factors which they believe contribute to that gap are similar to those which are commonly addressed in the literature on females in math and science. Among these factors are:

*Computer users:* Girls observe that most computer users are male--in their schools, in the home, and in the media.

*Mathematics association:* Because computers are associated historically with number crunching; the fact that they are used more often in math-related courses; and the fact that math teachers are most frequently the computer teachers; females associate computers with math and masculinity.

*Machines:* Computers are perceived as machines (and often introduced as machines first), and because females are not socialized to be comfortable with machines, they are uncomfortable using computers.

*Software orientations:* Much software--both educational and recreational--is male-oriented with orientations toward war, death, and destruction, or sports. For example, how many software programs give feedback by having something explode, having a missile hit a target having, a football go over a post, etc.

*Language:* Does computer "jock" suggest anything feminine to you?

*Male assertiveness in capturing computer time:* Boys, in their enthusiasm for computers, often sign up first for available time slots or will quickly run to and claim computer space while females, who are taught to be polite and wait their turn, are left out.

*Competing interests*: Desire for social content is a strong drive in the development of female adolescents, and young girls are not as likely to want to engage in the solitary activities often assigned as computer tasks.

My question is this, when we introduce computers or any other technology, have we given adequate thought to the existing differences in the ways young girls may be seeing the technology? Do we have to take the computer apart and learn all of its parts on the first day? Is that most likely to generate an interest by females? (By the way, I am certainly *not* suggesting that we be condescending or diminish the value of computers to females by introducing it as a machine that will store recipes either!) It seems as if we have not adequately addressed these questions; rather, we have introduced a new technology in such a way as to provide further differentiation.

It also seems important to include a revision of textbooks at every level if we hope to impact the female student and her interests and aspirations. The current texts are written by men with examples heavily slanted toward the male experience and with an implicit assumption that whoever has chosen to take the course brings an intrinsic motivation to learn whatever information, skills, concepts, etc. the books contain. The current texts do little to demonstrate the ways in which the knowledge of these disciplines contribute to the world, providing only token attention to the functions of science, mathematics, and technology in the everyday world or in careers. (My husband still asks me why he had to take trigonometry. He says he has rarely had to figure out the height of a building by measuring the height of a tree and the shadows of the building and the tree.)

It is also crucial that we not only examine content and teaching strategies such as hands-on versus textbook learning, but also that we look at some of the other more subtle ways in which we influence the attitudes of females toward themselves and toward science, mathematics, and technology. For example, under certain conditions, females have been shown to demonstrate significantly lower expectancies for success and consequently lower achievement when a task had a perceived "masculine" orientation even if there was no real difference in ability to achieve on the task. For example, Deaux and Farris (1977) reported that when an anagrams task was labeled masculine, women's performance expectancies were lower than men's; however, when that same task was presented as feminine, the performance *expectancies* were equal. House (1974) found that when tasks were presented under competitive conditions, females' expectancies for success were lower than those of females working alone or males working under either condition. All of this has led me to agree with Brophy (1985) that it is not enough to treat male and female students equally if gender differences are to be eliminated. Different, rather than identical, treatments may be necessary.

Finally, a thorough and complete assessment of all the factors which influence the choices made by young women necessitates an expansion of the definition of "environment" to include the scientific environment, the community of scientists, and even the cultural definitions of science. Evelyn Fox Keller has raised some intriguing questions in the book *Reflections on Gender and Science* which merit the attention of both scientists and educators. At a very fundamental level, this

mathematical biophysicist questions the labeling of one aspect of experience as feminine and another as masculine. Noting the popular mythology of science is to cast objectivity, reason, mind, and therefore, science as masculine; she points to the shortcomings of this image both to the development of the discipline of science and to the attraction of women to science. She notes:

> To both scientists and their public, scientific thought is male thought in ways that painting and writing--also performed by men--have never been . . . objectivity itself is an ideal that has a long history of identification with masculinity. The fact that the scientific population is, even now, a population that is overwhelmingly male, is itself a consequence rather than a cause of the attribution of masculinity to scientific thought . . . Now that the women's movement has made such naked assertions [about the fact that women cannot be good scientists] offensive, open acknowledgement of the continuing belief in the intrinsic masculinity of scientific thought has become less fashionable. It continues, however, to find daily expression in the language and metaphors we use to describe science. When we dub the objective sciences "hard" as opposed to the softer (that is, more subjective) branches of knowledge, we implicitly invoke a sexual metaphor, in which "hard" is of course masculine and "soft" feminine. . . . A woman thinking scientifically or objectively is thinking "like a man" (pp. 77-78).

Keller is quick to point out that success in the scientific world for the time being will require the assumption of the roles, the attitudes and the values currently associated with the profession. However, her belief is that scientists will come to recognize the degree to which their "objective beliefs" are really biased and her hope is that ultimately science will not be gender stereotyped in its thinking or in the public's perceptions. We can only hope that the same can happen in mathematics and engineering.

Unfortunately, we have only scratched the surface of a complex issue here. We have not dealt with the media, the toys we provide as parents and teachers, the subtleties of our culture, and the messages which present conflict and unresolved issues to young women who are making decisions about their careers. However, any steps we can begin to take will make us better off tomorrow than we are today.

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## Discussant Reaction:
## Bright Girls in Math and Engineering

**Nicholas Colangelo**

This is going to be hard because what I want to do is make some comments that will not be repetitive of what Dr. Malcolm and Dr. Callahan have said. They have covered many things that I have found in my own research and my own work with gifted girls and with gifted boys. So by not mentioning certain things, I am actually confirming them. I will try to get to some other points that I think would be of interest.

First of all, something that has been glossed over so far: It was mentioned fleetingly . . . let me go back to the Maccoby and Jacklin study of 1974 where in essence their literature review said that somehow or another boys come out higher in verbal areas. In my neighborhood, what that comes down to is that boys can put two and two together, and girls can read the handwriting on the wall. That kind of thinking has permeated the way we think about boys and girls. Anyone who does not fit that mold we usually think of as an "exception" rather than the rule. Now, there is some evidence which is pretty clear and hard to ignore. I do research with ACT (American College Testing), and I'll share some of that research with you. Certain trends do come out by gender; let's take a look at the reading and verbal scores.

First of all, there is an excellent longitudinal study done by David Martin and H. D. Hoover called "Sex Differences in Educational Achievement: A Longitudinal Study" (1987), reported in the *Journal of Early Adolescence*. The article reviews a number of studies indicating that across the nation and for many years, little girls have beaten little boys in measures of reading and verbal skills. As a nation, this fact doesn't get our attention at all. Everyone says, "So what?" And the magnitude of what girls have over boys is much higher than the magnitudes that are reported in terms of boys' mathematics and quantitative reasoning. This is important because we are not dealing with just gender differences, but with things we choose to focus on and things we don't. There are males who have majored in English, decided to be English professors or English teachers. Most of the time, if a young man is going to go into English or wants to teach English, usually the deterrent is that there aren't many jobs in the field or that there isn't much money associated with the area. No one ever implies that males aren't quite as good as females in English and perhaps they shouldn't get into something they can't really do. It's not even thought of. Let me make the other point. When girls think about a mathematics or science field there is an innuendo that it really isn't their turf. They must be either pretty exceptional or they have some nerve. And yet we don't do this to males. We don't say, "Are you going to go into something that requires verbal skills?" We don't imply "Are you sure you can tackle something that is not male turf?" We don't even think of it that way. We assume that if you, as a male, make that decision, then you've got enough skills to succeed. But we don't assume the same thing with girls. Another point--somehow our society has decided that it is more important to be good in mathematics and science than in reading and verbal skills. How that came about is a bit more that I can put my finger on, but I think it's interesting that the area that girls are strongest in is not valued. It could be coincidence; it might not be.

A third issue: Dr. Malcolm talked about course-taking. Let me give you some other information about course-taking practices. An ACT research report by Lange, Engen, and Maxey (1987) looked at the relationship between ACT scores and course-work. ACT tests are supposedly more curriculum-based than SAT (Student Aptitude Test) so that the kinds of courses that a student takes should have some impact on the scores on the ACT. What they found is that there is a correlation between course-taking and ACT scores, but what is especially interesting is that the correlation is really only strong with mathematics and science courses, but is not very strong with English or Social Studies. What this suggests is that if you don't learn mathematics in a formal mathematics course, you are not going to learn it because it's not the kind of thing that the kids down the street talk about. If you don't learn science in a formal science-type course, you probably won't pick it up. Whereas in English, and especially in Social Studies, there are things you can learn by watching television, by chatting with others, or by reading *Time* magazine. You can pick up enough information to help you score well on ACTs. So when we talk about coursetaking, we have to be more specific than just coursetaking; it is specifically mathematics and science curriculum that has a greater bearing on levels of achievement. Dr. Malcolm and the ACT report provide similar evidence indicating that girls take significantly fewer mathematics and science courses at the advanced level. In order to score very high on the ACT, it is necessary to go beyond the basic introductory mathematics and science courses. I think that, as counselors, as educators, every time we allow a girl to easily opt out of mathematics and science classes, we are helping that girl close a door on her future; the same thing is true with boys.

Dr. Malcolm also brought up in her paper that many students do not realize the kinds of doors that will close on them in college if they have weak mathematics or science backgrounds. They are often told that they can go back and make up courses that they missed. In reality, life doesn't work that way. A lot of kids have fooled themselves by thinking they can go to college and be anything that they want to be. That is quite untrue and it's becoming less true. Many state schools have what is referred to as a "semi-open door" policy, which means that any state resident in the top half of his or her class can attend a state university. However, what the brochures don't say is that you have to have certain averages to get into specific majors. The front door is fairly open but all the little doors inside aren't, and so many of the students who get into the State University cannot get into the specific field they anticipated they were going to get into, and they end up in a holding pattern. The holding pattern is a euphemism for a General Studies or Liberal Arts program, and the discipline that was supposed to enhance people's thinking has become something of a dumping ground because all of the other disciplines have become more selective. Those are the kinds of things that I think we have to be very careful of, because those doors started shutting several years before these students went to college.

A piece of research that needs to be talked about is the Camilla Benbow and Julian Stanley research report in 1980 that stated: 1) That at the highest level, boys significantly out-score girls on SAT tests of mathematical reasoning; 2) That when you control for coursework, boys still out-score girls at the high school level in mathematics reasoning when using the SAT. So their comment, as reported in *Science*, was that coursework is not a legitimate explanation for differences in mathematics reasoning by gender at high levels. What they said is that you have

to take a look at perhaps others things, perhaps socialization and endogenous variables. That causes quite a furor because it does begin to sound like "inherent ability," and whenever we are going to talk about ethnicity, whenever we're going to talk about gender, people don't want to hear that heredity may be a significant variable. I believe there is a portion of the population who believe there are genetic or biological differences when it comes to mathematics ability. A study such as Benbow and Stanley will receive considerable "press." The results even appeared in the *New York Times* and *Science*.

I would like to make a comment from Jacquelynne Eccles. She reported in the *Educational Researcher* (June/July, 1986) that one of the issues young girls are faced with if they decide to go into mathematics or engineering is that it is not a personal choice anymore. These girls are representing all womanhood, and I think that puts a lot more pressure on career decisions. Eccles believes that one of the reasons why a lot of high ability girls deliberately do not go into math or engineering is that they simply prefer other areas. Even though they are capable, they would just as soon not go into mathematics and science because they are positively attracted to something else. One of the things we have to be careful of whenever our microscope is on a group (e.g, gifted girls) is to respect a legitimate choice by girls who have the ability to go into mathematics and science but choose not to, rather than making the accusation that they are "copping-out." These girls are in a difficult position. I think the day will come that girls, like boys, will make decisions on the basis of what they want to do. Right now, promising girls in mathematics and science do not have that luxury.

Another point from Helen Farmer (1987): She says that when a society doesn't support mathematics and science for girls, as Dr. Malcolm's paper documents, then the roles of parents and teachers are much more important. Parents and teachers are more influential in helping girls gifted in mathematics and science make decisions than they are in helping boys, because there is more risk-taking involved for girls. And when there is more risk-taking, mom and dad's "Hey, you can do it" is a lot more powerful than when the child chooses a field that is appropriate or acceptable.

There was a time in this country when for a young woman to go to law school was a major accomplishment. Or to go to medical school. Today, it's not the revolutionary move for women to go to law school or medical school, but it is to go into engineering. If I may digress with a comment about medical school: Barbara Kerr and I (in press) have been doing some studies with ACT scores and preferences for majors and careers. It's interesting that even though the number of young women going into medicine is fairly large, their distribution among medical specialties is very uneven. There seem to be certain areas of medicine that they go towards and others areas that they don't. Somehow or another, as soon as women move in on something, the men leave. Most of the women going into medicine go into Pediatrics, OB-GYN, Family Practice. They do not go into surgery. You will find that there are real gender differences within specific areas of the medical profession.

The same thing can be said for the sciences. What Dr. Kerr and I found was that high-ability girls prefer biological sciences to the physical sciences. So we can't even talk about science in general; there seem to be tracks within science.

That seems to me the more subtle, the more destructive element, because sometimes, globally, it seems like things are equitable, but when you look closely, there are little trenches within.

I am going to go back to something that Dr. Callahan said about computers. I don't fully agree that what's happened is that males have taken to computers and females have not. What really has happened is that females are seen as good at the word processors. That's become their turf within the computer realm. Males use the computer as a computer and females use it as an "advanced" typewriter.

I have a couple of comments that I would like to make about ability and effort and this is somewhat of a speculation. When it comes to ability and effort, I think that, as a nation, we believe that mathematics and science are more tied to ability and English and Social Studies are more tied to effort. Most times we will not discourage people from going into the Social Sciences because of poor test scores. We will say things like, "Hey, if you're talking about majoring in Chemistry, you've got to be bright." But, if we are talking about History, we say, "Well, if you're willing to work hard, you can make it." So it's not just a matter of ability and effort per se, we even have certain preconceived notions that most anybody can probably be a Social Studies teacher, but you've got to be intellectually gifted to make it in math. I think these are the beliefs and messages we really need to take a look at in terms of ability and effort.

I want to share with you some findings from the ACT studies that I have been doing with Barbara Kerr. We have done a study of almost 800,000 students who took the ACT in 1985-86. We wanted to take a look at the kinds of kids who typically go to college (the upper 80th percentile); the moderately talented (the top 5 percent); what we call the highly talented (the top 1 percent). First of all, engineering is definitely the drug of choice among talented kids in high school in terms of a college major. While engineering is definitely the top choice, it is overwhelmingly chosen by talented boys compared to talented girls. Now if a female scores in the 99th percentile, it's the same as if a male scores in the 99th percentile. So ability cannot account for the difference in major and career preference. Thirty-two percent of the 99th percentile boys and 9.9 percent of the girls said that they wanted to become engineers. What we cannot figure out is why so few of the 9.9 percent of the girls of the highly talented actually pursue engineering. The boys who threaten to be engineers, for the most part, carry out that threat. The girls who threaten, don't. That's what concerns us. What happens between a young girl with ability saying, "This is what I'm interested in," and failing to pursue it? That's the point at which I think many of the issues raised by Dr. Malcolm come to the forefront.

The other part of the ACT study has to do with science. Biological sciences: at the top 1 percentile, 14.1 percent of the females are interested in biological sciences, and 3.9 percent of the males. When it comes to physical sciences, of students in the top 1 percentile: males, 11.1 percent; females, .8 percent. You see the segregation by gender even in the kinds of sciences. It has nothing to do with ability because, again, you are talking about the top 1 percent of both males and females.

Interestingly, talented girls are more interested in pursuing a mathematics career than are talented boys (according to our data). At the 95th percentile, 2.4 percent of the females versus 1.7 percent of the males choose math as the preferred career. At the 99th percentile, it's 5.6 percent of the females versus 4.4 percent of the males. In kids with that kind of ability, girls are more interested in mathematics majors and careers than boys but someplace along the line, they don't live out the decision the way that boys do.

I would like to share with you how talented youngsters rate education as a potential major and career choice. The higher the score on the ACT, the lower the desire to pursue a career in education. That had better start concerning us as a nation. At one time, because we were such an effective sexist and racist nation, we could rely on a steady supply of the brightest women and minorities to be in teaching. That steady supply is no longer viable. Only 4.8 percent of the kids at the 99th percentile were interested in pursuing education as a future. From our data, it seems the great portion of our future teachers is going to come from those who score below the 80th percentile. That's going to have some ramifications in terms of the future of our educational system.

I want to say a couple of things about counseling. Pat Casserly (1979) did an interesting study for Educational Testing Service (ETS) about high-ability girls in mathematics and science, and counseling. One of the things she found was that school counselors in her sample actually discouraged high-ability girls from pursuing majors and careers in mathematics and science. This was by both male and female counselors. Casserly offered two reasons for the findings: One was that the counselors themselves feared mathematics and science and passed that fear to the girls. Two was that many of the counselors felt that it was difficult enough for boys to get jobs in these areas and that girls would just cause more problems by competing with the main breadwinner. Look at the kinds of subtle and overt messages that bright girls were getting.

When I was at Madison, Wisconsin, we observed counseling sessions with gifted boys and girls and most of these sessions were about career and college choices. One of the things we observed in a small sample was that often when bright girls said that they wanted a career that would take considerable graduate work like law and medicine, the counselors would say, "Have you thought about how this fits in with having a family?" Now that is a legitimate question because it's something that they should think about. However, it was never brought up with gifted boys. If it is a legitimate question, then boys ought to think about what their career plans mean in terms of family. The fact that it was brought up only with girls suggests the implied message, "You may be doing something that is less than wonderful."

Bright girls in our society are being subtly and overtly dissuaded from thinking about careers in mathematics and engineering. This form of sexism is not only destructive to the youngster, but destructive to the entire society. I see that a major purpose of this conference is for us to generate ways to combat this sexism.

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